BITTERROOT SWAT MODEL
QUALITY ASSURANCE PROJECT PLAN

Prepared By:

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DEQ Task Order Number 202104-05

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David Clark, HDR Project Manager   Date

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DOCUMENT PURPOSE

This Quality Assurance Project Plan (QAPP) has been written to support Soil Water Assessment Tool (SWAT) modeling activities within the Bitterroot Watershed, Montana Department of Environmental Quality (DEQ) Task Order Number 202104-05 between Land and Water Consulting, Inc. and HDR Engineering, Inc. It has been prepared to outline the quality assurance and control procedures that will be implemented during Task 1: Data Compilation and Assessment, Task 2: Model Development, Task 3: Model Review and Calibration, Task 4: Model Documentation, and Task 5: Model Application.

The QAPP has been completed under the direction of, and for use by Montana DEQ to ensure that (1) modeling input data are valid and defensible, (2) model setup and calibration protocols are followed and documented, and (3) model application and output data are reviewed and evaluated in a consistent manner.

LIST OF ACRONYMS

ACRONYM

ASTM	American Society of Testing and Materials
ARS	Agricultural Research Service
AVSWAT	ArcView Soil Water Assessment Tool
BASINS	Better Science for Integrating Point and Nonpoint Sources
CAFO	Centralized Animal Feeding Operation
CD	Compact Disk
COE	Coefficient of Efficiency
DEQ	Montana Department of Environmental Quality
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FTP	File Transfer Protocol
FWP	Montana Fish, Wildlife, and Parks
GIS	Geographic Information System
GRASS	Geographic Resources Analysis Support System
HDR	HDR Engineering, Inc.
HRU	Hydrologic Response Unit
HUC	Hydrologic Unit Code
MBMG	Montana Bureau of Mines and Geology
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Landcover Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NSC	Normalized Sensitivity Coefficient
NWIS	National Water Information System
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QUAL2E/K	Enhanced Stream Water Quality Model
SOPs	Standard Operating Procedures
SOW	Scope of Work
SWAT	Soil Water Assessment Tool
TAC	Technical Advisory Committee
TAMU	Texas A&M University
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VNRP	Voluntary Nutrient Reduction Program
WQA	Water Quality Act
WWTP	Waste Water Treatment Plant

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1.0   INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has incorporated the use of simulation data produced from environmental models as part of the quality assurance (QA) planning process under Order 5360.1 A2, "Policy and Program Requirements for the Mandatory Agency-wide Quality System" (EPA, 2000). Specifically, a Quality Assurance Project Plan (QAPP) is required for modeling projects where simulated data is used to interpret, extend, or serve as a surrogate for measured data. The Bitterroot Soil Water Assessment Tool (SWAT) QAPP, herein referred to as QAPP, presents in specific terms the elements of quality assurance and quality control (QA/QC) that will be implemented in order to achieve the data quality objectives and acceptance criteria for Total Maximum Daily Load (TMDL) development within the Bitterroot Watershed. The QAPP will: (1) document the type and quality of data needed to employ an effective modeling approach, (2) establish model setup and calibration methods that are consistent with the established objectives and project-specific requirements, and (3) ensure that managers and planners make sound and defensible scientific decisions based on modeling results.

This plan has been prepared in accordance with the guidelines in the 1998 EPA Guidance for Quality Assurance Project Plans (EPA QA/G-5, 1998) and EPA Guidance for Quality Assurance Project Plans for Modeling (EPA QA/G-5M, 2002).

1.1   Approach

A graded approach has been used for the Bitterroot project in order to apply an appropriate QA level with the confidence needed in modeling results. The fundamental requirements that define the QA level include:

- The Intended Use of the Model – Higher standards are required for projects that involve potentially large consequences.

- The Scope and Magnitude of the Project – The more complex the project and model are, the more detailed the QA effort should be.

Although there are no explicit categorizations or guidelines for applying the graded approach, a generalized methodology has been identified in QA/G-5M – Guidance for QAPPs for Modeling (EPA 2002). It allows QA activities to be adapted to meet the rigor needed for the project at hand. If a project addresses regulatory compliance or TMDL implementation, such as in the case of the Bitterroot, significant QA planning is necessary. The Bitterroot SWAT Model QAPP has been prepared accordingly.

2.0   SECTION A: PROJECT MANAGMENT

2.1   Section A4: Project and Task Organization

The Bitterroot SWAT Modeling Project has been funded by the EPA and Montana DEQ to support TMDL planning within the Bitterroot Basin – HUC 17010205, part of DEQ Task Order Number 202104-05 between Land and Water Consulting, Inc. and HDR Engineering, Inc. Montana DEQ is the overall project sponsor and supervisor of the Bitterroot project and will provide management and oversight in accordance with the TMDL goals of the department. Responsibilities of DEQ over the course of the project will consist of routine communications with the contractor and cooperating partners, coordination and QA/QC of all project deliverables, organization of the Technical Advisory Committee (TAC), and final verification and approval of the contractor records including data and reports generated as part of the study. DEQ staff will work directly with the Contractor (HDR, Engineering, Inc.) to oversee the modeling effort and ensure the project is moving along in a timely manner.

Integral DEQ in- house personnel include the Project Officer and QA Officer. They are part of a larger project team that includes EPA-Region 8, HDR Engineering, Inc., Land and Water Consulting, Inc., and the Technical Advisory Committee (Figure 2-1).

Figure 2-1. Project Organization Chart

HDR Engineering, Inc. (HDR) has been sub-contracted through Land and Water Consulting, Inc. for model development and calibration. HDR is the preferred consultant because they have an existing relationship with the Montana DEQ and are knowledgeable about the Bitterroot River Watershed, its issues, and stakeholders. They will keep DEQ updated of all sub-tasks and shall be responsible for submitting monthly status reports to document the progress of the project. Specific project management duties of HDR will include correspondence with the DEQ Project Officer via telephone, email, or fax; interaction with the technical advisory group; and communication with Land & Water regarding internal contracting issues.

The HDR manager will be available for conference calls and meetings, and will ensure high quality service to DEQ. He or she will work hand-in-hand with the DEQ to: (1) address the status of work for each active delivery order, (2) conduct as-needed briefing sessions, (3) oversee all work performed by HDR, (4) respond to inquiries or questions regarding work progress, and (5) provide direct and immediate access to HDR's technical resources.

Land & Water has been pre-qualified through the State Procurement Bureau to provide environmental services. Their role in the project will consist of contract administration with DEQ and sub-contracting. Key points of contact for technical or contractual issues include the DEQ Project Officer, HDR and Land & Water Project Managers, and technical support personnel (Table 2-1).

Table 2-1. Key Project Personnel

Key Personnel	Title	Contact Information
Kyle Flynn	Montana DEQ Project Officer	(406) 444-5974
Mark Bostrom	Montana DEQ QA/QC Officer	(406) 444-2680
David Clark	HDR Engineering, Inc. Manager	(208) 342-3779
Michael Kasch	HDR Engineering, Inc. Modeler	(208) 342-3779
Paul Callahan	Land and Water, Inc. Manager	(406) 721-0354

A Technical Advisory Committee (TAC) will be used as a resource for project management, oversight, and peer review of the SWAT modeling activities. The TAC will provide significant input during the model construction, calibration, validation, and reporting phases. They are important to DEQ in providing a representative and defensible modeling product. Prospective TAC members include the Montana Bureau of Mines and Geology (MBMG), U.S. Forest Service (USFS) and Rocky Mountain Research Station, Montana State Agricultural Extension, Plum Creek Timber, University of Montana, Missoula County Health Department, and Ravalli County Planning Department.

2.1   Section A5: Problem Definition and Background

In accordance with the Montana Water Quality Act (WQA) [Montana Codes Annotated 75.5.101, et seq. (2003)], the State of Montana must monitor the extent to which the state's surface waterbodies support legally designated beneficial uses. For those waterbodies in which one or more pollutants impair legally designated beneficial uses, the State must develop TMDLs and associated restoration plans for water quality improvement. Currently over thirty-five stream segments are listed as water quality limited within the Bitterroot Watershed. Of these, thirty-one are impaired for siltation or sediment; six from nutrient related causes. Four municipal wastewater treatment plants (WWTP), one industrial source, ten storm water permits, and at least one centralized animal feeding operation (CAFO) add to the complexity of nonpoint source pollution in the drainage.

Montana DEQ has been charged with the responsibility of developing TMDLs for the region and has determined that a modeling approach will be the most effective way to meet the decision-based objectives of the TMDL program. This stance will allow flexibility to address the broad range of stakeholder interests and water quality concerns in the drainage. A SWAT watershed loading and water quality model has been authorized to complete the TMDL

planning process in order to evaluate management and land use scenario changes within the Bitterroot drainage. The modeling tool will be used to complete point and non-point source loading analysis, allocate sediment and nutrients for TMDL development, and formulate water quality restoration plans. Additionally, it will support compliance with the 2002 numeric criteria mandated by the Clark Fork River Voluntary Nutrient Reduction Program (VNRP).

2.1.1　Model Selection

Montana DEQ has selected the Soil Water Assessment Tool (SWAT) for use in the Bitterroot. The SWAT is a watershed-scale loading model developed by the USDA Agricultural Research Service (ARS) and Blackland Research Center of Temple University to compute non-point source pollutant loads to stream and river systems. The model uses GIS technology, topography, soils, precipitation, plant growth, and urban and agricultural crop management information to form a complete deterministic definition of the hydrology and water quality of a watershed. Benefits of the SWAT approach are:

- The model is physically based. Watersheds can be modeled to evaluate the relative impact of changes in management practices, climate, and vegetation on water quality or other variables of interest.

- The model uses readily available inputs. The minimum data required to make a run are commonly available from government agencies.

- The mathematical solutions within the model are computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money.

- Long-term impacts spanning several decades can be studied. Gradual buildup of pollutants can be simulated along with the impact on downstream water bodies spanning several decades.

- The model code has been validated on hundreds of basins throughout the United States and abroad.

SWAT is supported by twenty years of applied non-point source research by the ARS to predict the impacts of land management practices on water, sediment, and agricultural chemical yields in complex watersheds with varying soils. It is a public domain model and has been applied extensively to support water quality and Total Maximum Daily Load (TMDL) planning throughout the United States. Further technical information regarding SWAT can be found at the following web address: http://www.brc.tamus.edu/swat.

2.2　Section A6: Project, Task Description, and Schedule

The project and task descriptions covered by the Bitterroot Modeling QAPP are described in the following sections. All are part of Task Order 5 between Montana DEQ and Land & Water Consulting, Inc. They include: Sub-task 1: Data Compilation and Assessment, Sub-task 2: Model Development, Sub-task 3: Model Review and Calibration, Sub-task 4: Model Documentation, and Sub-task 5: Model Application.

2.2.1   Task 1: Data Compilation and Assessment

Purpose: The purpose of Sub-task 1 is to assess and describe the data currently available for constructing a SWAT watershed-scale loading model of the Bitterroot River Watershed.

Approach: Watershed data in the Bitterroot are currently available from the following sources: DEQ, FWP, Tri-State Water Quality Council, U.S. Geological Survey (USGS), and National Climatic Data Center (NCDC-NOAA). DEQ has compiled much of this information prior to the initiation of the Bitterroot Project and will provide it in electronic form to HDR for use in model development. HDR will review the sufficiency of the data for development of a SWAT model and will coordinate with DEQ on the GIS requirements. Any deficiencies or assumptions will be addressed and documented.

Sub-task 1.1. Watershed Data: Watershed data are the primary input drivers of non-point source loadings to the SWAT model. DEQ will provide electronic copies of the relevant information via CD or FTP to HDR. GIS and water quality data required for SWAT model setup and calibration include, but are not limited to those identified below. All GIS data will have a single common projection.

- Digital Elevation (DEM 30m)
- Digital Ortho Quads (DOQs)
- Soils
- Land use and land cover (1992)
- Fire coverage
- Hydrography
- Stream Gage Locations
- Weather Stations
- Water features
- Point sources
- Climate
- Basins
- Geology
- Cities
- Infrastructure
- Transportation

Sub-task 1.2. River Data: In-stream quality and discharge data will be used to develop headwater and tributary sources to the model. The data will be provided to HDR by DEQ via CD or FTP and will include flow and water quality constituents.

Sub-task 1.3. Water Rights, Irrigation, and Land Use Management Data: DEQ will provide background material, local contact information, and data regarding water rights, irrigation, general land use practices, and management techniques that influence water quality in the Bitterroot watershed. This information will be used to setup the management files for hydrologic response units (HRUs) within each of the sub-basins in the SWAT model. It includes, but is not limited to, legal water rights, irrigation points of diversion, irrigation points

of use, irrigation practices, cropping and crop rotations, fertilizer application, and street or road maintenance practices (if vacuum swept).

2.2.2   Task 2: Model Development

Purpose: The purpose of Sub-task 2 is to construct a watershed-loading model of the Bitterroot River and tributaries using AVSWAT 2000, or the most current version of AVSWAT. The objective of Sub-task 2 will be to develop a functional non-point and point source model that adequately defines the Bitterroot Watershed and can be refined through calibration.

Approach: HDR will develop a single SWAT model, or series of three linked models (depending on model discretization), of the Bitterroot watershed by including the topography, soils, land use and land cover, system routing, initial and boundary conditions, and model coefficients. Model development will include the conversion of the data from Sub-task 1 into the necessary model input structure and management files.

Sub-task 2.1. Bitterroot River Modeling Criteria: DEQ will develop acceptable criteria for each of the three calibration points (USGS gages: near Connor, at Florence Bridge, and at Buck House Bridge) using the approach outlined in Section 2.4.2. Modeling criteria will be developed and presented in the form that defines the acceptable output criteria for calibration of hydrology and seasonal and annual loadings of water quality constituents (nitrogen, phosphorus, and suspended sediment).

Sub-task 2.2. Watershed Density and Model Descretization: HDR will develop a watershed-scale loading model using the most current version of AVSWAT that segments the watershed into Headwaters, Middle, and Lower basin calibration points. HDR will inform DEQ if any issues exist with the water quality and stream flow data that would preclude this model definition. In such a case, an alternative definition will be agreed upon by DEQ and HDR jointly. The density of the model and sub-basin descretization will be made in consideration of the schedule and resources available. At a minimum, however, all streams that have been listed on the state's 303(d) list as impaired by nutrients, sediment, or temperature will be included in the model definition.

Sub-task 2.3. Water Quality Fate and Transport: HDR will use the fate and transport water quality modeling capabilities of AVSWAT for the Bitterroot River from the headwaters to the confluence with the Clark Fork River. The stand-alone Bitterroot River QUAL2E (or QUAL2K) model may be used to crosscheck modeled output, or used entirely in its place.

2.2.3   Task 3: Model Calibration and Validation

Purpose: The purpose of Sub-task 3 is to calibrate and refine model output and define performance criteria for the model(s) developed in Sub-task 2.

Approach: HDR will perform SWAT model calibration according to the established modeling criteria identified in Section 2.4.2 of the QAPP. Depending on project needs and resources, they may provide an interim overview presentation of model development and

performance to the TAC and DEQ. Calibration or model refinements made by HDR will be based on comments from the QA/QC review.

2.2.4   Task 4: Model Documentation

Purpose: The purpose of Sub-task 4 is to prepare documentation that describes the model development and calibration of Sub-tasks 2 and 3.

Approach: Technical memoranda will be prepared during the project to track progress, decisions, assumptions, etc., and form the basis for a final modeling report that summarizes the model development and calibration. Modeling documentation will be a stand-alone technical report. It will contain the necessary detail to complete SWAT model setup and calibration, and accurately reproduce modeling results.

2.2.5   Task 5: Model Application

Purpose: The purpose of Sub-task 5 is to apply the SWAT model(s) to various land management and land use scenarios across the watershed that effect nutrient, sediment, and thermal loading. DEQ will be responsible for the development of specific management and land use scenarios that will be modeled in SWAT for TMDL planning and development. The objective of this effort is to ascertain the most feasible and effective land management strategies scenarios that will support designated beneficial uses and can be used develop TMDLs for nitrogen, phosphorus, suspended sediment, and temperature in the Bitterroot Watershed.

Approach: HDR will use the most appropriate model (AVSWAT or QUAL2E/K) to simulate watershed loading and in-stream conditions decided upon by DEQ. Scenarios will cover at a minimum, the potential continuum of growth and development in the foreseeable future. Model output for stream flow, nutrients, suspended sediment, and temperature from each scenario will be evaluated and included in a final modeling report that will be used in support of TMDLs and water quality restoration plans for the Bitterroot Watershed.

2.2.6   Schedule

The project schedule is included in Appendix-A.

2.3   Section A7: Quality Objectives and Criteria for Model Inputs and Outputs

Quality objectives and criteria for model inputs and outputs are qualitative and quantitative statements that (1) clarify study objectives, (2) define the appropriate type and acceptance criteria of existing data, (3) establish acceptable model input and calibration criteria, (4) outline model performance evaluation obligations, and (5) specify tolerable levels of potential decision errors. Each is discussed in the following sections.

2.3.1   Acceptance Criteria for Existing Data

Data of known and documented quality are essential to the success of the Bitterroot SWAT modeling project. These, in turn generate information for use in decision-making. Montana DEQ has established Data Quality Objectives (DQOs) for the Bitterroot SWAT

modeling project in order to specify the acceptance criteria for existing model input, and calibration or validation data. Bitterroot DQO's identify the (1) type and quality of data that will be appropriate for use in the Bitterroot SWAT modeling project, (2) spatial and temporal input data coverage requirements, (3) data quality and currency, and (4) technical soundness of the collection methodology. A bullet list of related requirements is shown below.

- All input and calibration data for the model will be of a known and documented quality.

- Data will be collected from as many sources as available, and provide the maximum temporal and spatial coverage of the Bitterroot drainage.

- The data will be comparable with respect to previous and future studies.

- Modeling data will be representative of the parameters being measured with respect to time, location, and the conditions from which the data are obtained.

DQOs for the SWAT model specifically include:

- The ability to quantify future spatial and temporal distribution of sediment and nutrients in the Bitterroot Watershed.

- Flexibility to evaluate historical and relative contributions of various pollutant sources in the Bitterroot Watershed.

- Adequate resolution to identify the relative in-stream impacts of pollutant loading to the stream system from various urban and non-urban non-point sources.

DQO's were further refined in order to define performance criteria that limit the probability of making decision-based errors. They address the data validity and reliability of the modeling effort and each is briefly described below in the context of completeness, representativiness, and comparability. The traditional context of precision and accuracy is not included due to the fact that the data has already been collected and analyzed through acceptable analytical procedures.

Completeness is a measure of the amount of valid input data obtained during a process [i.e. Sub-Task 1 - Data Compilation and Assessment (Section 2.2.1)]. The target completeness for the Bitterroot SWAT model will be 100 percent – e.g. all available sources included. The actual completeness may vary depending on the intrinsic availability of monitoring data. Deficiencies in water quality, climatic, or stream flow data are outside of the control of the modeling effort and will be addressed as part of the data compilation and assessment effort. In order to provide surrogate data, the most current statistical or stochastic methods will be used to extend or fill-in missing time-series data. The normal-ratio will be used to fill precipitation gaps. Discharges will be linearly interpolated or estimated using other fitting methods such as regression analysis. HDR will work with Montana DEQ to address any data issues as they develop.

Representativeness is a measure of how closely the SWAT input or calibration data will reflect the physical characteristics of hydrology and water quality over time. Standardized monitoring plan design and the use of Standard Operating Procedures (SOPs) for discharge measurement, soils identification, digital elevation model (DEM) production, land cover

mapping, sample collection and handling, and acquisition of weather data are crucial to ensuring representative data quality. All SWAT model input or calibration data sources will have a QAPP in place prior to the use in the Bitterroot effort, when possible. References to the SWAT input data sources are identified in Section 3.2, Method of Acquiring the Input Data. The use of existing data with a known quality record will ensure that the SWAT modeling effort in the Bitterroot yields accurate predictions, with an acceptable level of model uncertainty.

Comparability expresses the confidence with which one data set can be compared to another. Data comparability from external sources is very much tied to the individual project methodology and time at which it was collected. For the purpose of the modeling effort, comparability will be maintained by using consistent units, appropriate temporal scales, and reproducible methods. Unit conversions (metric is the required default for SWAT), datum transformations, and grid re-projections will likely be required to make data for the modeling comparable. Information that exists outside a reasonable temporal scale, e.g. where LULC has significantly changed, or the installation of a reservoir or new wastewater treatment facility will potentially alter modeling results, are not comparable. DEQ will make these determinations, as necessary. Comparability between other model indicators will be evaluated on a case-by-case basis with the support of the modeling team.

Assessing whether the DQOs have been achieved for a modeling study is less straightforward than for a typical sampling and analysis program. The usual data quality indicators (e.g., completeness, representativeness, comparability) are difficult to apply and in many cases do not adequately characterize model output. The ultimate quality test for the Bitterroot SWAT model is whether the output sufficiently represents the natural system that is being simulated. To a large extent, this is determined by the expertise of the modeling teams and the amount of available data. Nonetheless, there are objective techniques that can be used to evaluate the quality of the model performance and output. The methods, and the proposed performance expectations, are discussed in the following sections.

2.3.2   Acceptance Criteria for Model Calibration

The acceptance criteria for model calibration define the procedures whereby the difference between the predicted and observed values of the model are within an acceptable range, or are optimized. Often calibration is the only method to ensure that model predictions correlate with values observed in the field. Calibration uses observed hydrometeorological data in a systematic search for parameters that yield an acceptable fit of computed results. This search is performed to find a reasonable best estimate that will yield the minimum value of an objective function, or variable that is critical in application.

Calibration has become increasingly important with the need for valid and defensible models for TMDL development. Acceptance criteria for the Bitterroot project were established by the Montana DEQ prior to the initiation of the effort in order to provide a numerical ruler for determining whether the SWAT model is an appropriate tool for TMDL decision-making. The model calibration criteria are based on the recommended error percentages for seasonal, annual, and storm-based water yields (Table 2-1). Generalized information related to model calibration criteria, and validation considerations, include the following references: Thomann, 1982; James and Burges, 1982; Donigian, 1982; ASTM, 1984; Wells, 2005.

Table 2-1. Acceptable Model Calibration Hydrology Criteria

Errors (Simulated-Observed)	Recommended Criteria
Error in Total Volume	10%
Error in 50% Lowest Flows	10%
Error in 10% Highest Flows	15%
Seasonal Volume Error – Summer	30%
Seasonal Volume Error – Fall	30%
Seasonal Volume Error – Winter	30%
Seasonal Volume Error – Spring	30%
Error in Winter Storm Volumes	20%
Error in Summer Storm Volumes	50%

Graphical comparisons of model performance can be made through time series plots of observed and simulated flows and state variables, and residual scatter plots (observed versus simulated values). Time series plots are generally evaluated visually for agreement, or lack thereof, between the simulated and observed values. When observed data are adequate, or uncertainty estimates are available, confidence intervals can then be calculated so they can be considered in the model performance evaluation.

A number of statistical tests are also available for watershed model evaluation and optimization. The Sum of the Squared Residuals and the Nash & Sutcliffe Coefficient of Efficiency are two that have been identified for the purpose of the Bitterroot SWAT modeling project. They can be used upon approval by DEQ. Each is described below.

Sum of Squared Residuals is a commonly used objective function for hydrologic model calibration. It compares the difference between the modeled and observed ordinates, and uses the squared differences as the measure of fit. Thus a difference of 10 feet^3/second between the predicted and observed values is one hundred times worse than a difference of 1 feet^3/second. Squaring the differences also treats both overestimates and underestimates by the model as undesirable. The function implicitly is a measure of the comparison of the magnitudes of the peaks, volumes, and times of peak of the hydrographs and water quality constituents. The equation for calculation of the sum of least squares is shown below (Diskin and Simon, 1977).

Sum of Squared Residuals

$$Z = \sum_{i=1}^{i_n} [q_o(i) - q_s(i)]^2$$

Where:

Z = Sum of Least Squares

q_o = Simulated Discharge

q_s = Observed Discharge

Nash and Sutcliffe Efficiency is a goodness-of-fit test recommended by the developers of the SWAT model as a statistical method for evaluating the hydrologic variability between measured and predicted model values. The Nash and Sutcliffe Coefficient of Efficiency (COE) provides a normalized estimate of the relationship between the observed and predicted model values and and is calculated as below (Nash and Sutcliffe 1970).

Nash & Sutcliffe Efficiency

$$\text{COE} = 1 - \frac{\displaystyle\sum_{i=1}^{i_n}[q_o(i) - q_s(i)]^2}{\displaystyle\sum_{i=1}^{i_n}[q_o(i) - \overline{q}_o(i)]^2}$$

Where:

COE   = Coefficient of Efficiency
q_o = Simulated Discharge
q_s = Observed Discharge

A COE value of one indicates a perfect fit between measured and predicted values for all events. COE values between zero and one suggest a positive relationship between observed and predicted values, thus allowing for the use of predicted values in lieu of observed data. A value of zero indicates that the fit is as good as using the average value of all the measured data. The Nash and Sutcliffe Efficiency test is endorsed by the ARS and Texas A&M University (TAMU), both of who support model research and development.

2.3.3   Model Validation

Validation is defined as the comparison of modeled results with independently derived numerical observations from the simulated environment. Model validation is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses the range of variables and conditions that are expected within the simulation. Although there are several approaches to validating a model, perhaps the most effective procedure is to use only a portion of the available record of observed values for calibration. The rest is used for validation. Once final calibration parameters are developed, simulation is performed for the remaining period of observed values and the goodness-of-fit between recorded and simulated values is reassessed. This type of split-sample calibration and validation procedure will used for the Bitterroot SWAT modeling project.

The credibility of the Bitterroot SWAT model hinges on the deterministic ability to predict conditions over the entire range of observed data: in effect, validating the model. For flow and water quality simulations where continuous records are available, multiple validation techniques will be used. Comparisons of simulated and observed state variables will be performed for daily, monthly, and annual values. Statistical procedures mentioned in Section 2.3.2 will be used to assess the calibration. These include error statistics, correlation and model-fit efficiency coefficients, and goodness-of-fit tests. For sediment and water quality data, model performance will be based primarily on visual and graphical presentations because the frequency of observed data is often inadequate for accurate statistical measures.

2.3.4   Acceptance of Model Sensitivity

Sensitivity analysis determines the effect of a change in a model input parameter or variable on the model outcome. The sensitivity of a model parameter is typically expressed as a normalized sensitivity coefficient (Brown and Barnwell, 1987). The methodology for identifying the sensitivity of a model parameter is shown below.

$$\text{Normalized Sensitivity Coefficient (NSC)} = \frac{\Delta Y_o / Y_o}{\Delta X_I / X_I}$$

Where:

ΔY_o = Change in the output variable Y_o
ΔX_i = Change in the input variable X_i

HDR will qualitatively assess the sensitivity of SWAT model parameters during manual calibration through parameter perturbation and use of the SWAT calibration tool. A summary of model sensitivity will be included as part of the project reporting. Details will include the variables modified for model calibration, the percent modification (e.g. $\pm 10\%$), percent change in the modeling results, and the normalized sensitivity coefficient (Table 2-2). The reporting format is shown below.

Table 2-2. Sensitivity Coefficient

Model Parameter	% Perturbation	% Change	NSC
Curve Number	-15%	-29%	2.2
Soil Available Water Capacity	20%	25%	1.3
Channel Erodibility	05%	01%	0.1

Algorithmic techniques for sensitivity and uncertainty assessment are available through several water quality modeling programs (Monte Carlo Simulation, first-order error analysis, or automated objective function optimization). Unfortunately, the current version of SWAT does not support these options. A new version is currently in Beta-test and will potentially be available as the project unfolds.

2.3.5   Acceptance of Model Uncertainty

Uncertainty is broadly defined as the lack of knowledge regarding model input parameters and the processes the model attempts to describe. Our ability to define model uncertainty is marginalized by our limited ability accurately describe complex processes. As a result, all engineering computations are attended to a degree of uncertainty due to the simplification of natural process and the limitations of input and calibration data. Computed values differ from observed ones, and the magnitude and frequency of these differences characterize the uncertainty of the best model estimate (Beard, 1996).

Uncertainty analysis is the terminology associated with the examination of how the lack of knowledge in model parameters, variables, and processes propagates through the model structure as model output or forecast error. Sources of model uncertainty were characterized by

Montana DEQ during the initial stages of Bitterroot SWAT planning in order to better understand how the model input data and parameters would potentially influence model output and prediction. Potential sources of model uncertainty include:

(1) Estimated model parameter values.
(2) Observed model input data.
(3) Model structure and forcing functions.
(4) Numerical solution algorithms.

Montana DEQ will be responsible for conducting uncertainty analysis (as resources permit), unless otherwise specified as part of contractual modifications with HDR. The project budget will be a large part of this determination.

2.4   Section A8: Special Training Requirements or Certification

A comprehensive review of technical services was completed prior to the contracting of the Bitterroot project in order to limit the formal training requirements for the project. Consequently, special training requirements or certifications are not needed for the modeling study personnel. SWAT training is provided by TAMU (if desired), and is considered an acceptable substitute for project experience, depending on the number of years in professional practice and licensure. The DEQ Project Officer will make these determinations, as required. Additionally, training can be provided by one or more of the senior modelers. The only requirement is that project personnel are expected to read and observe the QAPP in order to be project certified.

2.5   Section A9: Documentation and Records

2.5.1   Technical Reporting

Four separate technical reports will be generated as part of the Bitterroot Modeling project. The modeling team will develop a central file repository for the information and data used in the preparation of any reports. HDR and DEQ will supervise the use of materials in the file. The following information will be included:

- Reports and documents prepared as part of the project.

- The project QAPP.

- Contract and work assignment information.

- Copies of e-mail correspondence with critical information or that document important project decisions.

- Technical review correspondence, data quality assessments, and performance audits.

- Significant communications (technical memoranda, internal notes, telephone conversation records, letters, meeting minutes, and all written correspondence between Montana DEQ, HDR, and other modeling team members).

- Maps, photographs, and drawings.

- Studies, reports, documents, and newspaper articles pertaining to the project.

- Special data compilations.

The records of receipt, and information on source and description of documentation shall be filed along with the original data to ensure traceability. Records of such actions and subsequent findings will be kept for processing. Examples include unit conversions, data gap interpolation, and data extrapolation. Recordkeeping shall also include example calculations and conversions, and software references for data processing (e.g., name of software, provider, version, etc.).

A summary of the Bitterroot SWAT modeling project deliverables is presented below. The anticipated dates of the deliverables are included in Appendix-A of this document.

1. **Task 1 Deliverable:** The Data Compilation and Assessment Report will be drafted in MS Word format summarizing the extent of water quality and stream flow data at the three USGS calibration stations (Bitterroot River near Conner, Florence Bridge, and Buck House Bridge) and any tributary streams. The report will note key limitations of the data and provide a summary of water use by stream within each modeling subbasin (i.e. allocated water rights).

2. **Task 2 Deliverable:** The Model Construction Report will contain documentation in MS Word format that sufficiently describes the model construction and all assumptions and management file definitions applied for various hydrologic response units. The deliverable will include a portable copy of the models burned to a CD, along with information on model discretization, number of subbasins and HRUs, stream reach designation, and proposed calibration points.

3. **Task 3 Deliverable:** The Model Calibration Report will be written in MS Word format and will cover the model development and calibration process. It will include a set of portable models and associated files, and will be provided as both a bound hard copy document. The deliverable will sufficiently describe model construction and calibration steps including all assumptions and management file definitions applied for various hydrologic response units. In addition, comparison of the calibrated hydrology and water quality loadings to the established modeling criteria will be completed at all calibration points.

4. **Task 4 Deliverable:** A final modeling report will be supplied both as a bound and hard copy document that will include the set of modeling scenarios and electronic models and associated files. The final modeling report will be developed as a separate MS Word document and will document the development, calibration, and application of the models. The report will be provided as both a bound hard copy document and electronic copy on CD. The electronic deliverable will include a set of portable models and associated files. The final report will incorporate all previous interim memoranda and correspondence, the datasets and assumptions used in the model development, calibration steps and methodology, and a comparison of model outputs to established modeling criteria.

2.5.2   Modeling Journal

A modeling journal will be kept to identify the internal model parameters that were adjusted during the calibration process to meet the criteria identified in Section 2.4.2. Although the use of a journal is not specifically identified in the SOW, it is encouraged that the contractor keep a record of all calibration iterations made during the project, along with the justification and professional reasoning behind the changes. Each time that a separate SWAT model calibration run is completed, changes should be documented in the journal. The level of detail in the model calibration journal should be sufficient to allow another modeler to duplicate the calibration method given the same data and model.

The modeling journal will include complete recordkeeping of each step of the modeling process. The documentation will consist of information addressing the following items:

- Model assumptions.
- Parameter values and sources.
- Input file notations.
- Output file notations and model runs.
- Calibration and validation procedures and results from the model.
- Intermediate results from iterative calibration runs.
- Changes and verification of changes made in code.

All data files, source codes, and executable versions of the computer software used in the modeling study will be retained for auditing or post-project reuse. These include:

- Version and source of the executable code used.
- Calibration input and output data.
- Validation input and output data.
- Model application input and output (i.e., for each scenario studied).

2.5.3   Correspondence

All correspondence related to the project (i.e. technical memorandums, significant emails, telephone contact records, and progress reports) will be kept by the Contractor and DEQ for the project duration, as well as a seven-year period after the termination of the project. Interim progress reports and technical memoranda will be prepared as the project develops to track progress, decisions, and assumptions. These, along with the data review, model setup and development, and calibration reports, and peer review comments generated by the modeling TAC will form the basis of the final report. All formal correspondence (technical memorandums and progress reports) between DEQ and HDR will be included in the final report.

If any changes in this QAPP are required during the study, a memo will be sent to each person on the distribution list describing the change(s). Each individual will be responsible for attaching a copy of each memo to his or her copy of the QAPP.

3.0   SECTION B: MEASUREMENT AND DATA ACQUISITION

Standard calibration and data management procedures will be implemented during the Bitterroot SWAT modeling project to ensure that modeling results are valid, reproducible, and comparable. The best, and most practical QA given the nature of the Bitterroot Modeling Project is the use of the following methods: (1) modeling techniques that are consistent within the professional industry, (2) calibration methods that can be performed repeatedly by a qualified person to obtain similar results, (3) documentation that is clear, concise, and thorough, and (4) the use of standard units for data management.

3.1   Section B7: Calibration

All models, by definition, are a simplification of the environmental processes they intend to represent. The optimization of empirical parameters that form the numerical basis of the model is referred to as calibration. Calibration iteratively adjusts model coefficients or parameters until predicted values accurately reproduce those measured in the field. SWAT has an internal calibration tool that aids the user in managing calibration scenarios and refining model runs until acceptable calibration criteria are met. Once an acceptable calibration is reached, the run can then be verified on an independent data set to judge the extent to which the model is able to predict hydrologic or water quality conditions over time. To best understand the calibration process, an overview of the SWAT modeling system is required.

3.1.1   SWAT Modeling System

The SWAT model requires a combination of watershed-based data to drive nonpoint source loadings to the model. Specific information required by SWAT includes data on river or stream hydrography, digital elevation model (DEM) files, land use and management information, weather data, and soils properties. A sequence of linked tools are used to provide the necessary framework to simulate water quality and hydrology for a single watershed, or a system of multiple hydrologically connected watersheds (Figure 3-1). These include:

(1) Data Pre-Processing.
(2) Watershed Delineation and Hydrologic Response Unit (HRU) Definition.
(3) Weather Station Input.
(4) Database, Input Parameterization, Editing, and Scenario Management.
(5) Model Execution.
(6) Read and Map-Chart Results.
(7) Calibration.
(8) Editing.

A geographic information system (GIS) is used as the computational and processing engine for initial model parameterization and setup. Important functional components, and the analytical capability of the ArcView GIS, are implemented in several sets of customized and user-friendly SWAT tools. The advantage of using a Windows-based SWAT interface is an ability to access SWAT databases, edit input management scenarios, execute the model, and read and analyze modeling results. Both the AVSWAT2000 and Better Science Integrating Point

Figure 3-1. SWAT Modeling System

and Nonpoint Sources (BASINS) extensions of the Environmental Systems Research Institute (ESRI) ArcView program are capable of this interaction.

3.1.2 SWAT Computational-Calibration Sequence

Quality and quantity constituents within SWAT are initially computed at the hydrologic response unit (HRU) level and then routed through the hydrologic network of subbasins in a series of channels. During manual calibration, model rate and export coefficients are adjusted within the HRU, and then at subbasin and stream reach level, until calibration criteria are met. Successive model runs are completed in a systematic search for parameters that yield the best fit of the computed results to the observed runoff.

A complete watershed model calibration involves a successive examination of the following characteristics of the watershed hydrology and water quality: (1) annual and seasonal water balance and streamflow, (2) sediment, and (3) nutrients. Simulated and observed values for reach characteristic are examined, and critical parameters are adjusted to attain acceptable levels of agreement. The refinement of calibration parameters should reflect the scientific literature and not exceed reasonability. The rationale for any model adjustments should be based on the calibration procedures outlined in Section 2.3.2 and documented as in Section 2.6. More specific procedures relating to the calibration of water balance, sediment, and nutrients are provided in Sections 3.2.1 through 3.2.3. Methods are largely amended from the SWAT 2000 User's Manual (Neitsch et. al, 2001).

3.1.3 Water Balance and Stream Flow

Adequate representation of the water balance and stream flow within SWAT is the first step to model calibration. Calibration is first done for average conditions. Once the run is calibrated for average annual conditions, the user can shift to monthly or daily records to refine the calibration. Observed and simulated results should be summarized as a comparison between the total water yield, baseflow, and surface flow (Table 3-1).

Table 3-1. Water Balance Calibration Summary Table

Scenario	Total Water Yield	Baseflow	Surface Flow
Observed	200 mm	80 mm	120 mm
Simulated	300 mm	20 mm	280 mm

Output values required for calibrating hydrology to subbasin outlets in SWAT are located near the end of the .std file entitled "Ave Annual Basin Values". Actual steps to optimize calibration of the hydrologic water balance are presented below.

1. **Calibrate Surface Runoff:** Adjust the curve number (CN2 in .mgt) until surface runoff is acceptable. If surface runoff values are still not reasonable after adjusting curve numbers use the soil available water capacity (±0.04) (SOL_AWC in .sol) or soil evaporation compensation factor (ESCO in .bsn or .hru) to calibrate the model.

2. **Calibrate Subsurface Flow:** Once surface runoff is calibrated, compare measured and simulated values of baseflow. If simulated baseflow is too high: (1) increase the

groundwater "revap" coefficient (GW_REVAP in .gw), (2) decrease the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw), or (3) increase the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw).

If simulated baseflow is too low, check the movement of water into the aquifer. If groundwater recharge (GWQ in .sbs or .bsb) is greater than or equal to the desired baseflow: (1) decrease the groundwater "revap" coefficient (GW_REVAP in .gw), (2) increase the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw), or (3) decrease the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw).

3. **Repeat:** Complete steps 1 and 2 until seasonal values are acceptable. This may take several iterations to get the surface runoff and baseflow correct.

Once average annual and annual surface runoff and baseflow are realistic, the temporal flow should be reasonable as well. A few problems may possibly persist. These include:

- **Peaks are reasonable but the recessions "bottom out".** Check the transmission losses for channel hydraulic conductivity (CH_K in .rte). For perennial streams that receive groundwater contribution to flow, the effective hydraulic conductivity of the channel should be zero. The only time the channel hydraulic conductivity would be greater than zero is for ephemeral and transient streams that do not receive continuous groundwater contributions to streamflow. A second variable that will affect the shape of the hydrograph is the baseflow alpha factor (ALPHA_BF in .gw). If daily steam flow is available, a baseflow filter program can be run to perform this analysis.

- **In snowmelt months, the peaks are too high and recessions are too low.** Check the values for maximum and minimum melt rates for snow (SMFMX and SMFMN in .bsn). These values may need to be lowered. Another variable that will impact snowmelt is the temperature lapse rate (TLAPS in .sub). Finally, the baseflow alpha factor may need to be modified (ALPHA_BF in .gw).

3.1.4   Sediment

There are two sources of sediment in the SWAT simulation: loadings from HRUs and subbasins and channel degradation or deposition. Once the ratio of surface runoff to baseflow contribution is being simulated correctly, the sediment contribution (loadings from HRUs or subbasins) should be close to measured values. In most situations, the user will probably have little information about channel degradation or deposition. If unable to assess the channel, it is suggested to adjust the loadings from the subbasins until they look reasonable and then assume that the remaining difference between actual and observed is due to channel degradation or deposition.

Average annual observed and simulated results should be summarized as the individual HRU load, average annual load leaving the stream reach, and observed total load, if available (Table 3-2). Individual HRU sources should be identified for literary comparison purposes.

Table 3-2. Sediment Summary

Source	Sediment	Average
HRU Load	2000 metric tons/yr	0.30 t/yr
Amount Leaving Reach	2600 metric tons/yr	
Observed Total Load	(if available)	

The sediment loadings from the HRUs and subbasins can be viewed by summing values for SYLD in either the .sbs or .bsb file. The amount of sediment leaving the reach can be obtained from values reported for SED_OUT in the .rch file. It is important to consider that reservoirs and ponds have a big impact on sediment loadings. If the amount of sediment being simulated in the watershed does not seem reasonable, first verify that all the ponds and reservoirs in the watershed are being properly simulated.

While surface runoff is the primary factor controlling sediment loadings to the stream, there are a few other variables that affect sediment movement.

1. Tillage has a significant impact on sediment transport. With tillage, plant residue is removed from the surface causing erosion to increase. Verify that the tillage practices are being accurately simulated.

2. Verify that the contouring and terracing of agricultural areas is accounted for in the support practices (P) factor of the USLE equation (USLE_P in the .mgt file). In general, agricultural land with a slope greater that 5% will be terraced.

3. There is usually a large amount of uncertainty in slope length measurements. The USLE equation slope length factor (SLSUBBSN in .hru file) will be affected by support practices used in the HRU.

4. Verify that the slopes given for the subbasin are correct in the HRU slope file (SLOPE in .hru file).

5. Ensure that USLE equation cropping practices (C) factor (USLE_C in crop.dat) reported for the plant cover is accurate for your area.

Channel degradation will be significant during extreme storm events and in unstable subbasins. Unstable subbasins are those undergoing a significant change in land use patterns such as urbanization. Variables that affect channel degradation and deposition include the linear and exponential parameters sediment re-entrained parameters (SPCON and SPEXP in .bsn file), the channel erodibility factor (CH_EROD in .rte), and the channel cover factor (CH_COV in .rte). These variables affect watershed sediment routing and can be calibrated to bedload data if available.

3.1.5   Nutrients

The nutrients simulated within SWAT are nitrate, soluble phosphorus, organic nitrogen and organic phosphorus. When calibrating for a nutrient, keep in mind that any changes will have an effect on all of the nutrient levels throughout the model. Nutrient calibration is most efficient when divided into two steps: (1) calibration of nutrient loadings and (2) calibration of

in-stream water quality processes. In order to calibrate nutrient loadings, the following steps need to be completed.

1. Check that the initial concentrations of the nutrients in the soil are correct. These are set in the soil chemical input file (.chm) and include: nitrate (SOL_NO3 in .chm), soluble P (SOL_MINP in .chm), organic N (SOL_ORGN in .chm), and organic P (SOL_ORGP in .chm).

2. Verify that fertilizer applications are correct. Check amounts, and the soil layer that the fertilizer is applied to. The fertilizer may be applied to the top 10mm of soil or incorporated in the first soil layer. The variable FRT_LY1 identifies the fraction of fertilizer applied to the top 10mm of soil. (If this variable is left at zero, the model will set FRT_LY1 = 0.20).

3. Verify that tillage operations are correct. Tillage redistributes nutrients in the soil and will alter the amount available for interaction or transport by surface runoff.

4. Alter the biological mixing efficiency (BIOMIX in .mgt file). Biological mixing acts the same as a tillage operation in that it incorporates residue and nutrients into the soil. This variable controls mixing due to biological activity in the entire watershed.

In addition to the variables mentioned previously, the user can modify the nitrogen percolation coefficient (NPERCO in .bsn file), phosphorus percolation coefficient (PPERCO in .bsn file), or phosphorus soil-partitioning coefficient (PHOSKD in .bsn file) to calibrate nutrient loadings. It is important to remember that organics are transported to the stream attached to sediment, so the movement of sediment will greatly impact the movement of organics. Finally, SWAT includes in-stream nutrient cycling processes as described in the QUAL2E Documentation. Variables in the watershed water quality (.wwq) and stream water quality (.swq) files control these processes.

3.1.6 Calibration Considerations

Calibration should consider the most important hydrologic and water quality response variables within the Bitterroot Basin. The sensitivity of these parameters has a significant influence on the uncertainty of the model and should be equally considered during the calibration process. Ideally, both high and low flow years, and the anticipated range of conditions and scenarios for which the TMDL will be developed will be used. Calibration should be completed in sequential order, using the most upstream point first and then moving downstream to the next point of calibration. It is important that parameters of files associated with the drainage area upstream of a calibrated point, are not changed during subsequent steps.

Following calibration, verification on an independent data set is necessary to evaluate the effectiveness of the model to represent physical processes beyond those that the model was calibrated for. A 6-7 year model "warm-up" period is recommended prior to any type of model performance review activities in order to account for soil moisture storage and temporal variability. Decisions made during model calibration and verification should be sufficiently documented so that an experienced user could complete the calibration process and obtain similar modeling results.

3.2   Section B9: Method of Acquiring the Input Data (Non-direct Methods)

As mentioned previously, a significant amount of watershed input data is required for setup and calibration of SWAT. Rather than outlining the input data acquisition process, web links to the direct source providers are shown below. Quality information can be viewed in subsequent links, along with information regarding development and disclaimers on use. A majority of the data originates from published agencies like USGS, EPA, USDA, DEQ and NCDC. The rigor in which these organizations implement QA/QC fully meet the quality objectives identified in Section 2.4.1 of the QAPP.

EPA STORET
http://www.epa.gov/storet/dbtop.html

National Climatic Data Center (NCDC)
http://www.ncdc.noaa.gov/oa/ncdc.html

National Elevation Dataset (NED)
http://nris.state.mt.us/nsdi/nris/el10/dems.html

National Hydrography Dataset (NHD)
http://nhd.usgs.gov/

National Land Cover Dataset (NLCD)
http://landcover.usgs.gov/index.asp

National Water Information System (NWIS)
http://waterdata.usgs.gov/nwis/

Remote Automated Weather Stations (RAWS)
http://www.fs.fed.us/raws/

Snow Telemetry (SNOTEL)
http://www.wcc.nrcs.usda.gov/snotel/

STATSGO Soils
http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/

The State of Montana Natural Resources Information System (NRIS) provides access to many of the sources identified above. Geographic information can be downloaded in several different projections including State Plane Coordinates and UTM Zone 12. The web link to the NRIS site is: http://nris.state.mt.us/gis/.

Similar to the model setup files, flow and water quality calibration data are also subject to the DQOs identified in Section 2.4.1. Several sources of effluent, discharge, and in-stream water quality data have been identified within the Bitterroot Watershed and include Montana DEQ, STORET, Missoula and Ravalli County wastewater treatment plants (WWTP), USGS, and the Tri-State Water Quality Council. A validated and approved QAPP from each of these

organizations certifies the data are acceptable for use in the Bitterroot project. Data with unknown quality (i.e. collected without a documented QAPP or using unapproved SOPs) will be flagged noted as either conditionally acceptable for limited use, or not acceptable for use at all.

3.2.1   Data Reconciliation

Provisional data, although helpful, will not directly be used for SWAT model input due to the fact that the information has not been scrutinized to the quality standards of the project. Exceptions will be validated on a case-by-case basis. If at any point during the course of the project a published data source appears to be unreasonable, or bias, (i.e. not representative or comparable) the data will be flagged and thoroughly reviewed. The decision on what to do with the data will be solely up to the DEQ QA Officer. All data will be reviewed for usability, general quality, and consistency with other data sources prior to use in the modeling activities. Limitations in the data sets will be acknowledged and included in discussions of their use.

3.3   Section B10: Data Management and Hardware and Software Configuration

Data used during the Bitterroot modeling project will be maintained in either hard copy or electronic format – depending on the nature of it. As a result, database entry and manipulation within the SWAT model is identified as one of the major preventable error sources in the modeling effort. Unlike the limitations of the model and model driver data itself, user induced error is correctable under an appropriate level of QA/QC. Multiple steps will be taken to ensure errors are minimized. Data formatting will be reviewed prior to the final version of the database being generated, including the data element type, format, allowable values and ranges, and other parameters.

All data used to populate the modeling database will be screened before upload to the SWAT model application. Manually entered parameter values from paper sources will be evaluated by reviewing printouts of summaries and randomly selecting portions of the model application. The review will include a comparison of the original data sources and paper documentation. Any record identified as having problems will be reviewed to determine whether corrected data can be acquired or the record omitted. The SWAT input files will be checked by HDR for reasonability and correctness prior to final model submittal to DEQ in order to detect errors that may occur during the data management or transfer process.

3.3.1   File Management

The file configuration and management structure of AVSWAT is important to the overall data management process of the modeling effort. SWAT systematically stores ArcView-based grids, shapefiles, and associated databases in a hierarchy that can facilitate efficient file transfer and ease of validation between users. Model input and output databases, calibration scenarios, and text files are stored as independent folders at the following location.

- C:\AVS2000\projectname\scenarios\default\

The pathway contains ArcView compatible database files and SWAT formatted ASCII input files. Direct ASCII model input and output for the SWAT Fortran executable are found in

the "txtinout" folder. Associated database tables that are linked to the ArcView interface are located in the "tablesin" and "tablesout" folders. Those files not parameterized during the initial GIS setup are required to be manually input to the model through a database import protocol. Microsoft Access or Excel (dbf version IV) is recommended for this process.

Specific files include, but are not limited to input and output control, land use management files, snowmelt parameters, and groundwater information. File notations, and brief explanations related to each of the SWAT modeling files describe the complexity of the data management process (Figure 3-2). More specific file storage information can be found by consulting the SWAT User's Manual (Neitsch et. al, 2001).

Figure 3-2. SWAT File Configuration

File	Description
.fig (watershed level file)	Watershed configuration file. This required file defines the routing network in the watershed.
file.cio (watershed level file)	Control input/output file. This required file contains names of input files for all watershed level variables and subbasin level variables.
.cod (watershed level file)	Input control code file. This required file specifies the length of the simulation, the printing frequency, and selected options for various processes.
.bsn (watershed level file)	Basin input file. Required file for watershed level parameters. Catch-all file.
.pcp (watershed level file)	Precipitation input file. This optional file contains daily measured precipitation for a measuring gage(s). Up to 18 precipitation files may be used in each simulation and each file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.tmp (watershed level file)	Temperature input file. This optional file contains daily measured maximum and minimum temperatures for a measuring gage(s). Up to 18 temperature files may be used in each simulation and each file can hold data for up to 150 stations. The data for a particular station is assigned to a subbasin in file.cio.
.slr (watershed level file)	Solar radiation input file. This optional file contains daily solar radiation for a measuring gage(s). The solar radiation file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.wnd (watershed level file)	Wind speed input file. This optional file contains daily average wind speed for a measuring gage(s). The wind speed file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.hmd (watershed level file)	Relative humidity input file. This optional file contains daily relative humidity values for a measuring gage(s). The relative humidity file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.pet (watershed level file)	Potential evapotranspiration input file. This optional file contains daily PET values for the watershed.
crop.dat (watershed level file)	Land cover/plant growth database file. This required file contains plant growth parameters for all land covers simulated in the watershed.
till.dat (watershed level file)	Tillage database file. This required file contains information on the amount and depth of mixing caused by tillage operations simulated in the watershed.
pest.dat (watershed level file)	Pesticide database file. This required file contains information on mobility and degradation for all pesticides simulated in the watershed.
fert.dat (watershed level file)	Fertilizer database file. This required file contains information on the nutrient content of all fertilizers and manures simulated in the watershed.
urban.dat (watershed level file)	Urban database file. This required file contains information on the build-up/wash-off of solids in urban areas simulated in the watershed.
.sub (subbasin level file)	Subbasin input file. Required file for subbasin level parameters. Catch-all file.
.wgn (subbasin level file)	Weather generator input file. This required file contains the statistical data needed to generate representative daily climatic data for the subbasins.
.pnd (subbasin level file)	Pond/wetland input file. This optional file contains information for impoundments located within the subbasin.
.wus (subbasin level file)	Water use input file. This optional file contains information for consumptive water use in the subbasin.
.rte (subbasin level file)	Main channel input file. This required file contains parameters governing water and sediment movement in the main channel of the subbasin.
.wwq (watershed level file)	Watershed water quality input file. This optional file contains parameters used to model QUAL2E transformations in the main channels.
.swq (subbasin level file)	Stream water quality input file. This optional file contains parameters used to model pesticide and QUAL2E nutrient transformations in the main channel of the subbasin.
.hru (HRU level file)	HRU input file. Required file for HRU level parameters. Catch-all file.
.mgt (HRU level file)	Management input file. This required file contains management scenarios and specifies the land cover simulated in the HRU.
.sol (HRU level file)	Soil input file. This required file contains information about the physical characteristics of the soil in the HRU.
.chm (HRU level file)	Soil chemical input file. This optional file contains information about initial nutrient and pesticide levels of the soil in the HRU.
.gw (HRU level file)	Groundwater input file. This required file contains information about the shallow and deep aquifer in the subbasin. Because land covers differ in their interaction with the shallow aquifer, information in this input file is allowed to be varied at the HRU level.
.res (reservoir file)	Reservoir input file. This optional file contains parameters used to model the movement of water and sediment through a reservoir.
.lwq (reservoir file)	Lake water quality input file. This optional file contains parameters used to model the movement of nutrients and pesticides through a reservoir.
recday.dat recmon.dat recyear.dat reccnst.dat (point source file)	Point source input file. These optional files contain information about loadings to the channel network from a point source. The type of file used to store the data depends on how the data is summarized (daily, monthly, yearly, or average annual).

3.3.2   Hardware and Software Requirements

SWAT is available in both ArcView 3.2 and Geographic Resources Analysis Support System (GRASS) GIS formats. It can also be run independently in MS-DOS. The ArcView version can be deployed using the AVSWAT2000 or EPA BASINS modeling extension, although each requires the use of the Spatial Analyst extension for calculation of grid-cell based parameters. Specific hardware computing requirements include a Pentium I processor or higher (166MHZ), 64 megabytes RAM, Microsoft Windows 95, 98, NT 4.0, or Win2000 operating systems (OS), and 300 megabytes of free memory for installation. A 2- gigabyte hard drive is recommended for storing the tables generated from the model.

4.0   SECTION C: ASSESSMENT AND OVERSIGHT

Assessment and oversight of the Bitterroot SWAT modeling project will largely be completed by internal and external review of the SWAT modeling products, contracted deliverables, and model performance. The frequency and type of each of assessment activity is discussed in the following sections.

4.1   Section C1: Assessment and Response Actions

4.1.1   Model Assessment and Selection

Model assessment and selection was completed prior to the initiation of the Bitterroot project by the Montana DEQ in order to identify a successful approach for non-point source modeling in the basin. As part of the review process, publicly available simulation models were evaluated in order to identify the most appropriate modeling tool for characterization of point and nonpoint sources within the Bitterroot Watershed. A number of standardized modeling packages were identified and reviewed by the Montana DEQ. They have the following advantages:

1. Comprehensive documentation is distributed including a user's manual, conceptual representation of the model process, explanation of theory and numerical procedures, data needs, data input format, and description of model output.

2. Technical support is typically provided in the form of training, use-support, and continual development from federal or academic research organization like EPA, USDA, and USGS.

3. Standardized modeling software has a proven track record, providing validity and defensibility when faced with legal challenges.

4. They are readily available to the general public (non-proprietary).

SWAT was ultimately selected due to its twenty-year development history, applicability at the river basin scale, and ability to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. There were no response actions required as part of the model assessment and selection process.

4.1.2   Model Performance Evaluation and Response

Due to the fact that the Bitterroot SWAT project is a modeling endeavor and not an environmental sampling and analysis project, traditional performance and system audits are not appropriate. Instead, the data generated as part of the modeling results will be evaluated during the validation process. Model performance assessments will be made continually by HDR, Montana DEQ, and the Bitterroot Modeling TAC as described in the calibration and validation process in Section 2.3.2. Performance audits will consist of comparison of model results with observed historical data, and general evaluation of model behavior for state variables and other output lacking historical data.

At the end of the calibration and validation period, the Montana DEQ and Bitterroot TAC will assess the ability of the model to predict hydrologic and water quality response over time. Criteria that will be included as part of the model performance assessment include:

- Modeling input and output validity.
- Model calibration and validation performance determination.
- Sensitivity and uncertainty analysis assessment.

Parameter deviation and post-simulation validation of predictions are major issues in the quality assurance framework. HDR will document the model data entry, parameter estimation, and calibration activities, and will provide this documentation to the DEQ as part of the project file. The DEQ internal assessment and Bitterroot TAC external assessment is further described in the following sections.

4.1.3 Internal Assessment

Modeling data, and project deliverables, will be internally quality controlled by Montana DEQ in-house review. Anticipated DEQ review staff members responsible for this process include the Project Officer, Bitterroot TMDL Planner, and QA Officer. The Project Officer will maintain overall responsibility for examining the contracted work to ensure that methodologies and processes are consistent with the procedures outlined in Section 3.0. He or she will provide advice to the QA officer of any deviations from the QAPP so that appropriate actions may be taken either to correct the problem, or amend the QAPP as needed. The DEQ Planner will participate in this review to a lesser extent. The QA officer will monitor the extent to which the QAPP is supporting its intended use. Other expertise will be called in, as required.

If the quality control audit results in detection of unacceptable conditions or data, the Project Officer will be responsible for developing and initiating corrective action. HDR staff will be notified in writing if the nonconformance relates to their work. Corrective response actions may include:

- Review or validation of modeling input and calibration data.
- Re-definition of model extents or spatial distribution.
- Performing additional SWAT model runs.
- Editing and modifying report deliverables.

HDR will meet all QA considerations prior to Montana DEQ acceptance of final report deliverables, modeling files, or modeling documentation.

4.1.4 External Assessments

Montana DEQ will also utilize an external peer-review by the Bitterroot Technical Advisory Committee (TAC). The TAC will be responsible for assessment and response actions in the form of project management, oversight, and performance evaluation of the project deliverables. Additionally, they will provide general assistance in model development, calibration, and verification.

A variety earth science and engineering disciplines have been identified by Montana DEQ as necessary to providing a representative and defensible SWAT modeling product in the Bitterroot. They include:

- Academic Research
- Agricultural Systems/Management
- County Planning and Health
- Forestry
- Hydrogeology
- Irrigation and Water Management
- Private Forestry
- Snow Hydrology
- Water Quality

DEQ has developed a web-based posting board through which much of the interaction of the TAC, DEQ, and contractor will occur. The structure will largely limit face-to-face interaction between the modeling team, but will reduce the burden of meeting attendance and streamline communication through a rich threaded discussion. The posting board will be available for active participation and interaction between modeling team members.

4.2   Section C2: Reports to Management

Given that the focus of the Bitterroot SWAT project is on modeling rather than data collection, there will be no formal QA reports generated or submitted to management. However, appropriate and timely technical reports are required as a key component of project performance. The project requires the submittal of the following four reports to management:

- Final Data Compilation and Assessment Report
- Final Model Construction Report
- Final Model Calibration-Validation Report
- Final Modeling Report

Both hard copy and digital versions are required in order to ensure a contiguous data transfer between parties. All reports will be peer reviewed, in conjunction with the final draft of this Quality Assurance Project Plan. Additionally, HDR will provide Montana DEQ with monthly progress reports describing the status of the project, accomplishments during the reporting period, activities planned for the next period, and any special problems or events. These can be submitted once a month, or during each invoicing period.

On-time completion of the modeling deliverables is essential to meeting TMDL deadlines. Deliverable dates for each of these projects are included in the project schedule in Appendix A.

5.0   SECTION D: DATA VALIDATION AND USABILITY

The data review, verification, and validation process identifies whether the final data package for the Bitterroot Modeling Project conforms to the quality standards of the Montana DEQ and EPA. Validation and verification criteria, as defined by this QAPP, are the standards that are used to determine whether the modeling results are sufficient for drawing conclusions related to the DQOs in Section 2.3.1.

5.1   Section D1: Departures from Validation Criteria

Random quality checks will be completed by Montana DEQ to ensure that modeling procedures and overall project objectives and validation criteria of the project are met. This will ensure that model predictions are reasonable, and that all work is consistent with the requirements of the QAPP. Additionally, the Bitterroot SWAT modeling deliverables are scheduled to undergo four levels of review and validation.

- In-house Consultant Review
- Montana DEQ Review
- Bitterroot TAC Review.
- EPA Review

Departure from validation criteria include any of the following review items: (1) failure to adequately compile and assess hydrologic, water quality, and meteorologic data for quality modeling purposes, (2) inability to develop a functioning and calibrated model that allows loading analysis and allocation to all 303(d) listed stream segments (as data permits), (3) non-compliance in the calibration and verification requirements of the project, or (4) refusal to produce the necessary report deliverables required as part of the project. Difficulty in meeting any of these requirements shall be reported to the DEQ Project Officer immediately, and will be addressed prior to final completion of the Task/Sub-task, or before a notice to proceed for the following Sub-task is issued.

If questions arise from about the quality of the modeling products, an independent review will be sought by the project team to ascertain the causes (if any). Any deficiencies found in the data by the QA Officer or the Project Officer will be documented in a fashion that describes the seriousness of the problem and will accompany a written statement of why the information will not be utilized.

5.2   Section D2: Validation and Verification Methods

The validation and verification methods used in the Bitterroot modeling project will focus on the data used for model input and calibration. Consequently extensive review procedures for SWAT input data will be implemented as part of the project. HDR will organize all data into a standard Microsoft Access database in order to make the necessary hydrologic, water quality, or weather related validation and verification queries. Quantitative screening procedures and database queries will be completed to identify all records outside of typical ranges for a given parameter. Those that are of questionable quality will be flagged and noted.

Values outside of the reported literature will not be used in model setup, calibration of model kinetic parameters, or model validation.

Information contained within the database will be checked by DEQ for accuracy on a selected fraction of records to ensure correct formula commands were entered into the program. If any of the data calculations are incorrect, all calculations will be rechecked after the correction is made to the database. Data quality will also be assessed by comparing the entered data to original data and by comparison of modeling results with the performance criteria summarized in Section 2. The cooperative use of these filtering techniques by DEQ and HDR to determine whether to accept, reject, or qualify the data. The calibration acceptance criteria in Section 2.3.2 will judge the extent to which the modeling results are accredited.

5.2.1 Validation and Verification Checklist

Montana DEQ will be responsible for final review of modeling products and performance and evaluation of the departure from validation criteria. A validation and verification checklist will be used for identifying whether the SWAT modeling products are completed to an acceptable manner, and with a documented quality. Validation and verification largely hinge on the calibration and validation presented previously in the document. Included are the following:

- Were appropriate input data used for model setup, calibration, and validation?
- Is the data of an appropriate temporal and spatial scale?
- Can TMDL considerations be addressed at the modeling scale?
- Was the model properly calibrated and verified?
- Were the calibration criteria or goodness-of-fit methods outlined in Section 2.4.3 used to access model performance?
- Does the model accurately reflect existing conditions and the range of physical processes and parameters that are within the professional literature?
- Is the necessary documentation prepared to address the deliverable requirements in the SOW?
- Has the model, and model documentation, been through the necessary review of the Montana DEQ and Bitterroot Watershed Modeling TAC?
- Were modeling scenarios developed within the spatial and temporal credibility of projected future conditions and the thresholds of the modeling limitations?

The validation and verification criteria have been included as part of the data usability checklist in Appendix B.

5.3 Section D3: Reconciliation with User Requirements

DEQ is committed to developing a representative modeling product and will ensure that: (1) complete documentation is maintained, (2) departures from validation criteria are addressed, (3) validation methods are properly documented, and (4) the modeling data is

properly reviewed. In this context, reconciliation with user requirements connotes establishing how model results will be tested and evaluated in order to ensure that the models are producing results of sufficient quality.

As part of the reconciliation process, the Bitterroot SWAT model deliverables will be reviewed by the DEQ Project Officer, QA Officer, and modeling TAC to assess whether the quality requirements of the QAPP have been met. The appraisal team and will complete a comprehensive review of the final model files and documentation and provide recommendations regarding the effectiveness of the SWAT model to be used in watershed planning and TMDL decision-making. The determination will largely be based on the effectiveness of the model to predict hydrologic and water quality response within the Bitterroot Watershed.

5.3.1   Model Limitations

It should be noted that all models are a simplification of the environmental processes they intend to represent. Although there is no consensus on model performance criteria in the literature, a number of basic statements are likely to be accepted by most professional.

- Models are approximations of reality and cannot precisely represent natural systems.

- There is no single, accepted test that determines whether or not a model is validated.

- Models cannot be expected to be more accurate than the sampling and statistical error (e.g., confidence intervals) in the input and observed data.

These considerations must be included in the development of appropriate procedures for quality assurance of the Bitterroot SWAT model. Despite a lack of agreement on how models should be evaluated, the following principles provide a final set of evaluation criteria for the Bitterroot SWAT modeling project.

- Exact duplication of observed data is not possible, nor is it a performance criterion for the Bitterroot project. The model validation process will measure the ability of the model to simulate measured values.

- No single procedure or statistic is widely accepted as measuring, nor capable of establishing, acceptable model performance. Therefore the combination of graphical comparisons and statistical tests are proposed to provide sufficient evidence upon which to base a decision of model acceptance or rejection.

- All model and observed data comparisons must recognize, either qualitatively or quantitatively, the inherent error and uncertainty in both the model and the observations. Model sensitivity and uncertainty will be documented, where possible, as part of this modeling study.

A margin of safety will be built as part of the modeling process to blanket model limitation and assumptions, and gage the impact on the usability of the results toward decision-based management.

6.0   REFERENCES

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APPENDIX – A

ID		Task Name	Duration	Start
1		**DEQ TASK 1: QAPP Development**	**25 days**	**Mon 2/21/05**
2		Review EPA Guidance Documents	2 days	Mon 2/21/05
3		Develop Draft QAPP	13 days	Wed 2/23/05
4		Technical Review	5 days	Mon 3/14/05
5		Submittal-Signatures	5 days	Mon 3/21/05
6		Deliver Final QAPP	0 days	Fri 3/25/05
7		**DEQ TASK 2: Modeling Technical Advisory Committee (TAC)**	**280 days**	**Mon 2/28/05**
8		Develop Potential List of TAC Members	5 days	Mon 2/28/05
9		TAC User's Web Forum	10 days	Mon 2/28/05
10		Send Invitation Letters	10 days	Mon 3/14/05
11		TAC Initial Meeting	15 days	Mon 3/28/05
12		TAC Support	245 days	Mon 4/18/05
13		End TAC Review	0 days	Fri 3/24/06
14		**HDR TASK 1: Data Compilation & Assessment**	**50 days**	**Mon 2/21/05**
15		Watershed Data	15 days	Mon 2/21/05
16		River Data	15 days	Mon 2/21/05
17		Water Rights/Diversions	15 days	Mon 2/21/05
18		Data Review	10 days	Mon 3/14/05
19		Draft Data Review Summary Report	15 days	Mon 3/28/05
20		Technical Review	5 days	Mon 4/18/05
21		Submittal	5 days	Mon 4/25/05
22		Final Data Compilation & Assessment Report	0 days	Fri 4/29/05
23		**HDR TASK 2: Initial SWAT Model Development**	**35 days**	**Mon 3/14/05**
24		GIS Analyses/Processing	5 days	Mon 3/14/05
25		Watershed Subbasin Development	20 days	Mon 3/14/05
26		HRU Discretization	10 days	Mon 4/11/05
27		Technical Review	5 days	Mon 4/25/05
28		**HDR TASK 2 (ctd): SWAT Model Parameterization**	**55 days**	**Mon 4/18/05**
29		Meteorologic Database Development	15 days	Mon 4/18/05
30		CN-AMC Database Development	15 days	Mon 4/18/05
31		Crop Rotation Database Development	15 days	Mon 5/9/05
32		Fertilizer Applicaton Schedule Database Development	15 days	Mon 5/9/05
33		Tillage Practices Database Development	15 days	Mon 5/9/05
34		Manning's "n" Database Development	15 days	Mon 5/9/05
35		Irrigation Database Development	15 days	Mon 5/9/05
36		Grazing Schedule Database Development	15 days	Mon 5/9/05
37		Timber Harvest Database Development	15 days	Mon 5/9/05
38		Groundwater Database Development	15 days	Mon 5/9/05
39		Draft Model Construction Technical Memorandum	10 days	Mon 5/30/05
40		Technical Review	10 days	Mon 6/13/05
41		Submittal	5 days	Mon 6/27/05
42		Deliver Functioning SWAT Model/Documentation	0 days	Fri 7/1/05
43		**HDR TASK 3: SWAT Model Calibration-Verification**	**110 days**	**Mon 7/4/05**
44		Initial Model Setup and Runs	15 days	Mon 7/4/05
45		Calibration	30 days	Mon 7/25/05
46		Verification	15 days	Mon 9/5/05
47		Sensitivity Analysis	10 days	Mon 9/26/05
48		Drat Model Construction/Calibration Report	30 days	Mon 10/10/05
49		Technical Review	10 days	Mon 11/21/05
50		Deliver Functioning Model Calibration Report	0 days	Fri 12/2/05
51		**HDR TASK 4: Model Documentation**	**40 days**	**Mon 10/10/05**
52		Prior Memorandum and Report Review	5 days	Mon 10/10/05
53		Draft Model Development Report	20 days	Mon 10/17/05
54		Technical Review	10 days	Mon 11/14/05
55		Submittal	5 days	Mon 11/28/05
56		Deliver Final Model Development Report	0 days	Fri 12/2/05
57		**HDR TASK 5: Model Application**	**80 days**	**Mon 12/5/05**
58		Run Modeling Scenarios	25 days	Mon 12/5/05
59		Work with TMDL Development on 303(d) Listed Waterbodies	10 days	Mon 1/9/06
60		Draft Final Modeling Report	30 days	Mon 1/23/06
61		Technical Review	10 days	Mon 3/6/06
62		Submittal	5 days	Mon 3/20/06
63		Deliver Final Modeling Report	0 days	Fri 3/24/06

Project: Bitterroot Project Schedule
Date: Tue 3/22/05

Task		Progress	
Split		Milestone	◆
Summary		External Tasks	
Project Summary		External Milestone	◆
Deadline	⇩		

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Project: Bitterroot Project Schedule
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Task / Progress / Summary / External Tasks / Deadline
Split / Milestone / Project Summary / External Milestone

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Project: Bitterroot Project Schedule
Date: Tue 3/22/05

Task	Progress	Summary
Split	Milestone	Project Summary

External Tasks | Deadline
External Milestone

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12	TAC Support	245 days	Mon 4/18/05
13	End TAC Review	0 days	Fri 3/24/06
14	**HDR TASK 1: Data Compilation & Assessment**	**50 days**	**Mon 2/21/05**
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16	River Data	15 days	Mon 2/21/05
17	Water Rights/Diversions	15 days	Mon 2/21/05
18	Data Review	10 days	Mon 3/14/05
19	Draft Data Review Summary Report	15 days	Mon 3/28/05
20	Technical Review	5 days	Mon 4/18/05
21	Submittal	5 days	Mon 4/25/05
22	Final Data Compilation & Assessment Report	0 days	Fri 4/29/05
23	**HDR TASK 2: Initial SWAT Model Development**	**35 days**	**Mon 3/14/05**
24	GIS Analyses/Processing	5 days	Mon 3/14/05
25	Watershed Subbasin Development	20 days	Mon 3/14/05
26	HRU Discretization	10 days	Mon 4/11/05
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28	**HDR TASK 2 (ctd): SWAT Model Parameterization**	**55 days**	**Mon 4/18/05**
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34	Manning's "n" Database Development	15 days	Mon 5/9/05
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38	Groundwater Database Development	15 days	Mon 5/9/05
39	Draft Model Construction Technical Memorandum	10 days	Mon 5/30/05
40	Technical Review	10 days	Mon 6/13/05
41	Submittal	5 days	Mon 6/27/05
42	Deliver Functioning SWAT Model/Documentation	0 days	Fri 7/1/05
43	**HDR TASK 3: SWAT Model Calibration-Verification**	**110 days**	**Mon 7/4/05**
44	Initial Model Setup and Runs	15 days	Mon 7/4/05
45	Calibration	30 days	Mon 7/25/05
46	Verification	15 days	Mon 9/5/05
47	Sensitivity Analysis	10 days	Mon 9/26/05
48	Drat Model Construction/Calibration Report	30 days	Mon 10/10/05
49	Technical Review	10 days	Mon 11/21/05
50	Deliver Functioning Model Calibration Report	0 days	Fri 12/2/05
51	**HDR TASK 4: Model Documentation**	**40 days**	**Mon 10/10/05**
52	Prior Memorandum and Report Review	5 days	Mon 10/10/05
53	Draft Model Development Report	20 days	Mon 10/17/05
54	Technical Review	10 days	Mon 11/14/05
55	Submittal	5 days	Mon 11/28/05
56	Deliver Final Model Development Report	0 days	Fri 12/2/05
57	**HDR TASK 5: Model Application**	**80 days**	**Mon 12/5/05**
58	Run Modeling Scenarios	25 days	Mon 12/5/05
59	Work with TMDL Development on 303(d) Listed Waterbodies	10 days	Mon 1/9/06
60	Draft Final Modeling Report	30 days	Mon 1/23/06
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62	Submittal	5 days	Mon 3/20/06
63	Deliver Final Modeling Report	0 days	Fri 3/24/06

Gantt annotations: Verification — HDR Engineering; Sensitivity Analysis — HDR Engineering; Prior Memorandum and Report Review — HDR Engineering; Draft Model Development Report — HDR Engineering; Technical Review — HDR Engineering

ID	ⓘ	Task Name	Duration	Start	Gantt Chart
1		**DEQ TASK 1: QAPP Development**	**25 days**	**Mon 2/21/05**	
2	🔲	Review EPA Guidance Documents	2 days	Mon 2/21/05	
3		Develop Draft QAPP	13 days	Wed 2/23/05	
4		Technical Review	5 days	Mon 3/14/05	
5		Submittal-Signatures	5 days	Mon 3/21/05	
6		Deliver Final QAPP	0 days	Fri 3/25/05	
7		**DEQ TASK 2: Modeling Technical Advisory Committee (TAC)**	**280 days**	**Mon 2/28/05**	
8	🔲	Develop Potential List of TAC Members	5 days	Mon 2/28/05	
9	🔲	TAC User's Web Forum	10 days	Mon 2/28/05	
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48		Drat Model Construction/Calibration Report	30 days	Mon 10/10/05	HDR Engineering
49		Technical Review	10 days	Mon 11/21/05	DEQ/TAC
50		Deliver Functioning Model Calibration Report	0 days	Fri 12/2/05	12/2
51		**HDR TASK 4: Model Documentation**	**40 days**	**Mon 10/10/05**	
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Timeline headers: Nov 20, '05 | Nov 27, '05 | Dec 4, '05 | Dec 11, '05 | Dec 18, '05 | Dec 25, '05 | Jan 1, '06 | Jan 8, '06 | Jan 15, '06 | Jan 22, '06

Legend:
Task — Progress — Summary — External Tasks — Deadline
Split — Milestone — Project Summary — External Milestone

Project: Bitterroot Project Schedule
Date: Tue 3/22/05

| --- | --- | --- | --- | --- |
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Chart milestones/labels: DEQ/TAC, 3/24 (task 13), HDR Engineering (task 60), DEQ (task 61), HDR Engineering (task 62), 3/24 (task 63)
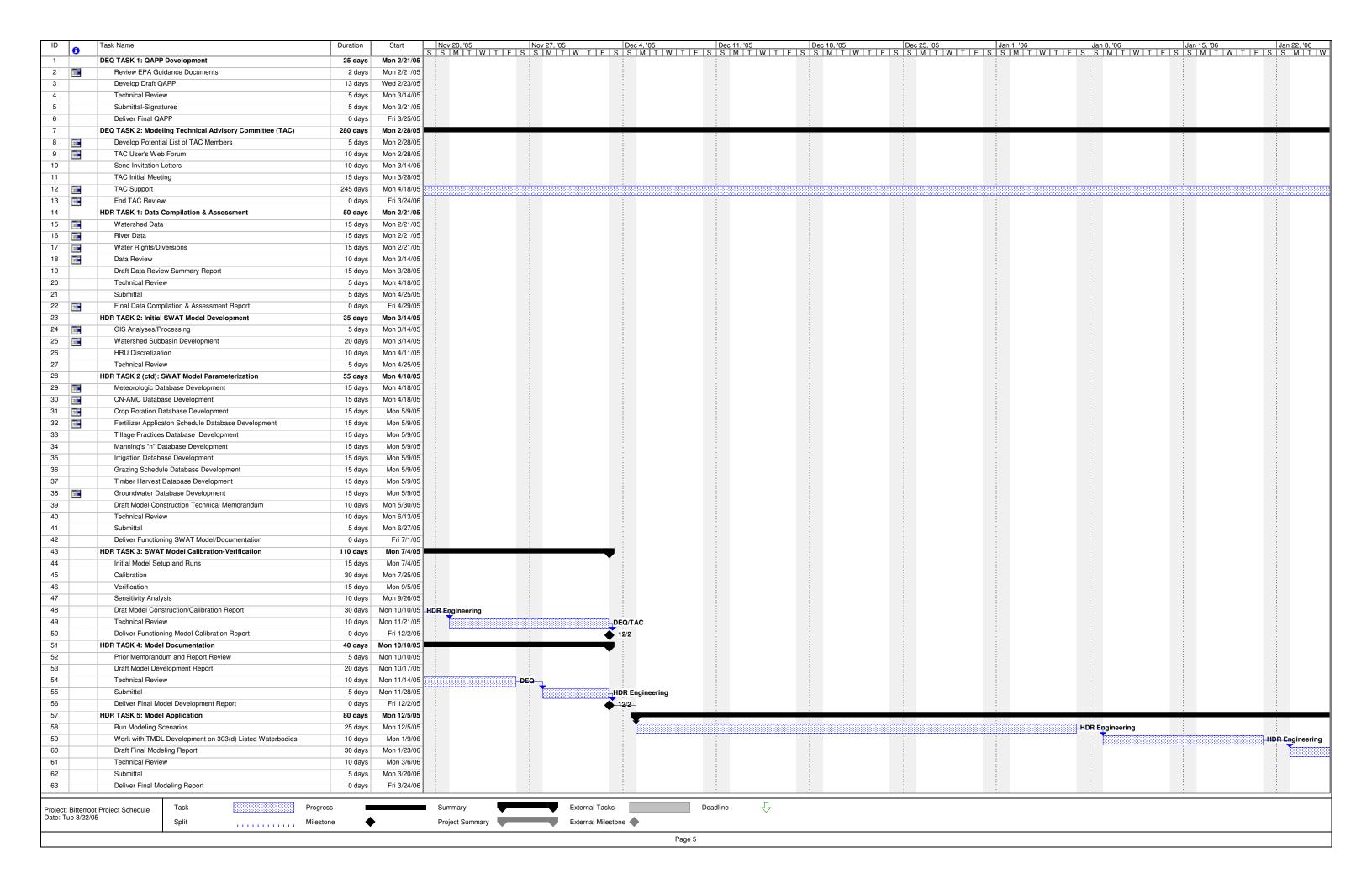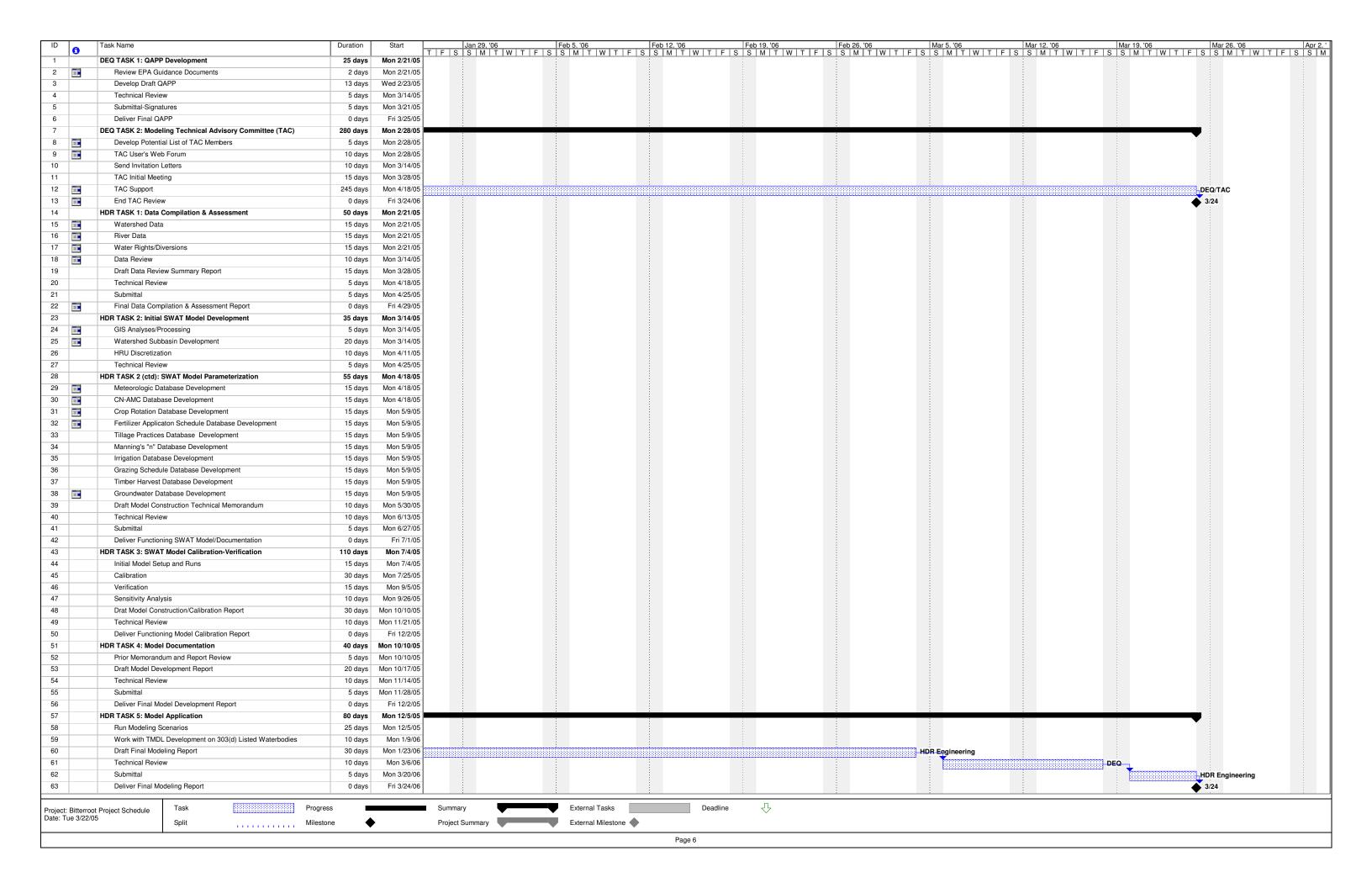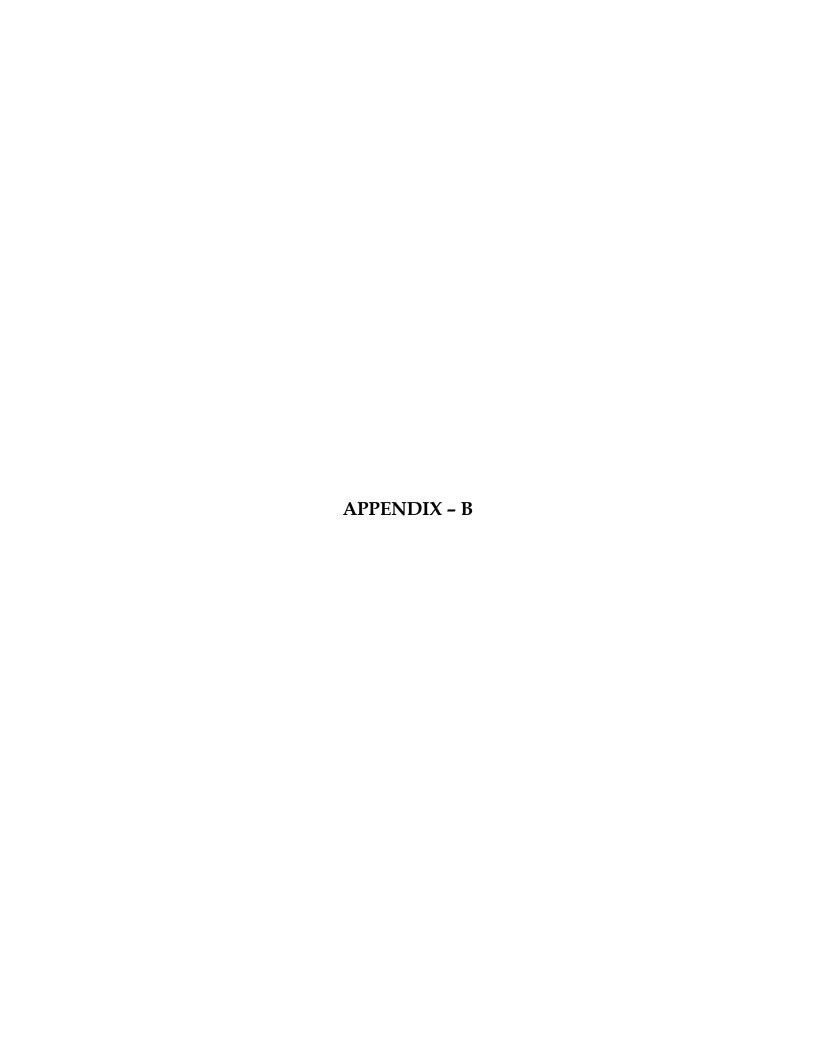
APPENDIX – B

BITTERROOT SWAT MODEL
VALIDATION AND VERIFICATION CHECKLIST

❑ **Were appropriate input data used for model setup, calibration, and validation?**

    ❑ All input and calibration data for the model were of a known and documented quality.

    ❑ Data was collected from as many sources as available, and provides the maximum temporal and spatial coverage.

    ❑ The data originates from an appropriate temporal and spatial scale.

    ❑ The data were comparable with respect to previous and future studies.

    ❑ Modeling data were representative of the parameters being measured with respect to time, location, and the conditions from which the data are obtained.

❑ **Can TMDL considerations be addressed at the modeling scale?**

    ❑ The model quantifies the spatial and temporal distribution of sediment and nutrients in the Bitterroot Watershed.

    ❑ The model has the flexibility to evaluate historical and relative contributions of various sources pollutant sources in the Bitterroot Watershed

    ❑ The model has adequate resolution to identify the relative in-stream impacts of pollutant loading to the stream system from various urban and non-urban point sources.

❑ **Was the model properly calibrated and verified?**

    ❑ Were the calibration steps followed according the SWAT User's Manual.

    ❑ Did calibration meet the requirements identified in Section 2.4.3.

    ❑ Were one of the calibration criteria or goodness-of-fit methods outlined in Section 2.4.3 used to assess model performance?

        ❑ DEQ Performance Criteria

        ❑ Sum of the Squared Residuals

        ❑ Nash Sutcliffe COE

       ❑ Graphical Tests

❑ Does the model accurately reflect existing conditions and the range of physical processes and parameters that are within the professional literature?

❑ **Is the necessary documentation prepared to address the deliverable requirements in the Statement of Work?**

    ❑ Final Data Compilation and Assessment Report

    ❑ Final Model Construction Report

    ❑ Final Model Construction Report

    ❑ Final Model Calibration-Validation Report

    ❑ Miscellaneous Correspondence, Technical Memorandums, etc.

❑ **Has the model, and model documentation, been through the necessary review of the Montana DEQ and Bitterroot Watershed Modeling TAC?**

    ❑ In-house Consultant Review

    ❑ Montana DEQ Review

    ❑ Bitterroot TAC Review

    ❑ EPA Review

❑ **Were modeling scenarios developed within the spatial and temporal credibility of projected future conditions and the thresholds of the modeling limitations?**

    ❑ Reasonable Spatial Variation

    ❑ Reasonable Temporal Variation

    ❑ Reasonable Land Use and Land Cover

    ❑ Reasonable Climatic Conditions

    ❑ Reasonable Management Practices